44. Two New Indian Species of the little-known Genus *Aulodrilus* Bretscher of the Aquatic Oligochæta belonging to the Family Tubificidæ.

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(Plates I.–III.† ; Text-figures 1–9.)

Contents.

(1) Introduction and Previous Work on the Genus.

The material which forms the subject of this paper was obtained from the mud at the bottom of a big pond known as Rewari-talab in Benares. This pond has its source of supply in the waste water from the city waterworks, in which the water from the Ganges is mainly used for the supply of the town.

In the same mud were also found many specimens of *Limnodrilus socialis* Stephenson and *Branchiura sowerbyi* Beddard, common Indian Tubificids; *Branchiodrilus hortensis* Stephenson, *Dero limosa* Leidy, and *Aulophorus furcatus* Oken, gilled Naidomorphs. Till recently the only Tubificidæ known from India were represented by four species, each belonging to a different genus. Besides *Limnodrilus socialis* and *Branchiura sowerbyi* there were only two other rather rare species, *Bothrioneuron iris* Beddard and *Monopylephorus parvus* Ditlevsen. In a paper just published (15) Stephenson has announced the discovery of *Tubifex tubifex* and *Aulodrilus remex* in that country. It appears that *Tubifex*, which is a common European Tubificid, is rare in India and probably in the East. The species described in the present paper belong to the genus *Aulodrilus*, which is at present the least known genus of the Tubificidæ. This genus was established by Bretscher (4) in 1899 for *A. limnobius* in Switzerland,

* Communicated by Dr. J. Stephenson, F.Z.S.

† For explanation of the Plates, see p. 969.

He places it as an appendix to the Tubificidæ, though he thinks that it fits neither with that family nor with the Lumbriculidæ, and suspects that it may be necessary to found a new family for it. Piguet (11) described a second species in 1906 and placed it among the Naididæ as *Naidium pleuriseta*; but later transferred it to *Aulodrilus*, which he considers to belong neither to the Tubificidæ nor to the Naididæ, as he saw retractile penes in front of the ventral setæ of segment 7. He did not complete the study of the worm, and so could not be sure about its position. Stephenson in a paper (15) published in 1921 describes another species, *A. remex*, from India as above-mentioned.

The genus, which hitherto has been characterized mainly by the character of the needle setæ (crotchets), is now well established, as will be seen from the following description. The genital organs, unknown to all the previous authors, are described at full length in the present paper and decide the position of the genus in the family Tubificidæ. The fact that the needle setæ possess a small outer prong (the one on the outer side of the curve of the shaft), which is not the usual condition in the Microdrili, is not of very great generic importance, because in some Tubificids, *e. g.* in *Tubifex velutinus* Grube, some crotchets of a similar kind are present; and moreover in *A. stephensoni* the outer small prong is missing altogether, the needle setæ being thus singly pointed and not forked.

The hinder end of the body is narrower and thinner, and does not show any signs of segmentation. Sometimes a faint indication of external segmentation may be visible, but the zone of budding lies some distance in front of the anus, where a large number of new segments are being formed. One can easily recognize the worm by its peculiar hinder end. This feature was previously described by Piguet in *A. pleuriseta*, and Stephenson has recently confirmed it in *A. remex*, and remarks "the most posterior region shows no proliferation, nor even any segmentation, but there is a zone of proliferation and formation of numerous new segments some little distance in front of the anus." Later on, he adds "such a budding zone as that of the present genus is so far as I know unique."

Aulodrilus connects the genera *Branchiura*, *Kawamuria*, *Psammorcytes*, and *Tubifex*; it also shows some resemblance to *Monopylephorus africanus* Michaelsen in the points that it possesses a spermiducal chamber, penial setæ and spermathecæ in the 9th segment. In certain points it also bears some similarity to the Naididæ. One point of similarity, namely the anterior position of the genital organs, is however merely a case of extreme variation within the genus *Aulodrilus* and hence not of any generic importance. This follows from the description here given of a second species, undoubtedly belonging to this genus, in which the reproductive organs lie in the usual position for the Tubificidæ. That it is a Tubificid is beyond any doubt, but it shows a greater simplicity of structure than any other genus of the family.

It is remarkable that the atrium here is situated far forwards, and is followed by a convoluted tube of great length which is enclosed in a thick covering of muscle fibres forming a structure somewhat similar to that of the cœlomic sac in *Branchiura* and *Kawamuria*. I have called the tube following the atrium and enclosed in the cœlomic sac the "atrial duct" and restricted the term atrium to the anterior rounded portion into which the prostate opens. The use of the muscle fibres forming the cœlomic sac, or better the muscular sac, is to evert the terminal part of the atrial duct, which thus projects out of the "spermiducal chamber" as a fairly long pseudo-penis.

The term "spermiducal chamber" used by Goodrich in the case of *Vermiculus* is retained here too, for a similar structure, *i. e.* the ventral depression of the body-wall, into which the atrial ducts open and the penial setæ lie.

The prostate gland as usual in the family is voluminous and composed of cells, which when full of secretion become disorganized and lose their cellular structure, the secretion being thus massed together flows directly into the atrium. The prostate appears to arise as a part of the atrial epithelium, which bursts out of the atrium as a sort of hernia or outgrowth.

The penial setal sacs are provided with masses of large pear-shaped gland cells, which lie in the body-cavity outside the setal sacs themselves though connected with their walls.

I wish to express my warmest thanks to Mr. F. A. Potts and Dr. J. Stephenson of Edinburgh for valuable suggestions in connection with this work.

(2) Diagnosis of the Genus and Species.

The chief characters of *Aulodrilus* are the following:—Dorsal setæ capilliform, uncinate or oar-shaped (with thin flattened distal extremity); ventral setæ uncinate. The uncinate setæ (crotchets) have the outer prong (the one on the outer side of the curve of the shaft) much smaller than the inner, or the outer prong may be absent. The penial setæ, of very different form, are the modified ventral setæ of the 7th or 10th segment. The atrium is small and subspherical; it is followed by a long convoluted atrial duct, which is enclosed by a thick covering of muscle fibres to form the "muscular" or "cœlomic sac." The terminal part of the atrial duct is capable of being evaginated to form a long soft pseudo-penis. The sperm-sac is formed by the backward extension of septum 6/7 or 9/10, and the ovisac by that of septum 7/8 or 10/11. The clitellum occupies segments 7 and 8, or 10 and 11. The spermathecæ lie in segment 6 or 9. The hearts are in segment 6 or 8. Supra-intestinal, sub-intestinal, and integumental capillary networks are absent. The formation of new segments takes place some distance in front of the anus. Asexual reproduction by fission as in the Naididæ does not take place.

Aulodrilus kashi resembles *A. remex* in possessing somewhat similar oar-shaped setæ in addition to the ordinary needles; but its hair setæ are longer than the needles. The first nephridium lies in the 11th or 12th segment. It is twice as long as *A. remex*. The genital organs are in segments 6 and 7, the clitellum is on segments 7 and 8, and spermathecæ are in the 6th segment; the spermiducal chamber occupies segment 7.

In *A. stephensoni* there are no oar-shaped needles, in which point it markedly differs from the above species. The needles are here singly pointed and not forked—a point in which it differs from all the other species. The genital organs here lie in segments 9 and 10, the clitellum extends over segments 10 and 11 and the spermathecæ are in segment 9. The penial setæ are the modified ventral setæ of the 10th segment.

(3) Aulodrilus kashi, sp. n.

(a) *Habits and External Characters.*

The worms live invariably in tubes formed of small foreign particles of sand and debris cemented together with mucus secreted by the glands in the skin; in the undisturbed condition the posterior portion generally remains outside the tube in the water, and is waved gently to and fro somewhat like the tail of *Tubifex*, *Limnodrilus*, and other Tubificids, while the anterior end and greater portion of the body remains buried in the tubes inside the mud. On being disturbed, however, the worms withdraw their freely moving tails with fair rapidity. When placed isolated in water, they do not come out of the tubes very readily, but when after a few minutes they do come out, they move like other Tubificids.

About 40 specimens of this form were obtained between February and April, of which 27 were sexually mature. They vary from 20–28 mm. in length and hence are much larger than *A. remex*. The hinder end of the worm is much thinner, the diameter being ·13 mm. The diameter near the anterior end is ·26 mm. The colour is yellowish-red due to the blood seen through the transparent body-wall.

The prostomium is bluntly conical, about 90 μ in length. The number of segments varies from 31–70, plus a considerable number of undifferentiated new segments, followed by a narrow terminal region of about ·78 mm. in length, which does not show any sign of segmentation (Pl. III. fig. 11). The number of new segments forming in the region of budding varies considerably, but it usually is large. The small narrow region behind the zone of proliferation and in front of the wide terminal anus Piguet regards as physiologically a gill. According to him it possesses a rich cutaneous vascular plexus, but this I have not been able to observe in my specimens. The anus can dilate during life, forming what Piguet calls a "branchial fossa." The anus is wide

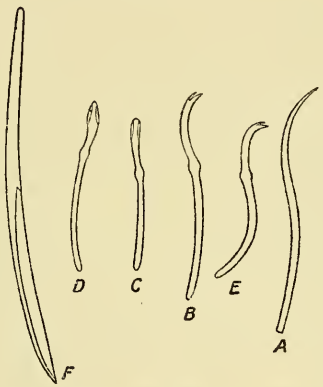
and terminal. The worms do not reproduce asexually by budding.

Setæ.—The setæ of both the dorsal and ventral bundles begin in the second segment, and are absent in a number of developing segments in front of the hinder end of the body.

There are three kinds of setæ in the dorsal bundles: capilliform, slightly hooked and doubly forked needles of the sigmoid type, and oar-shaped setæ with somewhat flattened or fan-shaped distal extremity, which sometimes may end in a fine point. The number of setæ in a dorsal bundle varies from 8–10 of which 2–4 may be capilliform; these are generally absent in the first two or three setigerous segments, and hence begin in the 4th or 5th segment.

A hair seta (text-fig. 1, A) is 99–104 μ in length, always

Text-figure 1.



A. Hair seta; B. Uncinate seta of a dorsal bundle; C and D. Dorsal setæ flattened near the distal end (oar shaped); E. Uncinate seta of posterior ventral bundle; F. Penial seta. × 540.

longer but more slender than the needle. It is nearly straight with a slight sickle-shaped curve and tapers to a fine point. The needles of the ordinary kind (text-fig. 1, B) are, as usual, doubly curved and slightly hooked at the distal extremity, which is forked. In length this seta varies from 75–92 μ; it bears a swelling or nodulus, which is situated much nearer the distal extremity, the proportions of the distances from it to the proximal and distal ends being about 2 : 1. The prong on the outer side of the curve of the shaft is smaller and much narrower than the one on the inner side, appearing as fine as a line or a denticle; in some preparations it may be broken off, and then the seta appears as a single pointed needle. The dorsal setæ of the third kind (text-fig. 1, C and D) are flattened at the distal extremity and appear oar-like. They

resemble the webbed setæ described by Lankester in *Tubifex*, but for the prongs at the sides of the web. The distal end may be either rounded or bluntly pointed. Their length as measured in two specimens is 66–69 μ in one and 78–80 μ in the other; the nodulus here also is situated near the distal extremity, the proportions of the distances proximal and distal to it being 2 : 1 as in the ordinary needles. The oar-shaped needles are less numerous and are often found in the segments in front of the middle of the body (in *A. remex* these setæ begin in segment 13 in one specimen and 7 in another, but they continue to the hinder end of the body). The thin flattened distal end shows comparatively faintly, is marked by one or two vertical lines and has not the distinct outline of the rest of the shaft.

The ventral setæ (text-fig. 1, E) are, generally speaking, similar to the forked needles of the dorsal bundles. The inner prong is much broader, about four times as thick or even more than the outer one, which looks like a fine process and in length may be as long as or slightly shorter than the inner one. The shaft of the seta in the posterior part of the body is shorter and more strongly curved than in the anterior part. In the anterior part of the body their length is 90–100 μ, in the posterior 60–70 μ. The nodulus is situated here also much nearer the distal end, the proportions being—the distance proximal to nodulus: distance distal to nodulus: 3 : 2 in the setæ in the anterior part, and about 2 : 1 in those of the posterior part of the body.

The penial setæ are always present during the sexual phase, and in this species are the modified ventral setæ of the 7th segment. They lie (Pl. I. fig. 1) inside the spermiducal chamber and posterior to the openings of the atrial (ejaculatory) ducts. In one specimen the penial setæ occupied a position anterior to these openings. Their number is 1–3, generally 2 per bundle. Their length is about ·25 mm. The form of the seta (text-fig. 1, F) is very different from that of any of the dorsal or ventral setæ. The shaft is slightly curved and is somewhat broadened in its distal portion; its tip comes to a fine point and looks somewhat like the end of a spear. The distal portion has a blade-like inner edge and an outer narrow thick border, which is continuous with the thick proximal part. There is a narrow longitudinal depression on one face of the blade, which gives it to some extent the appearance of a spoon. The breadth at the base of the shaft is about 7 μ, while at the distal expanded portion near the tip it is about 12 μ.

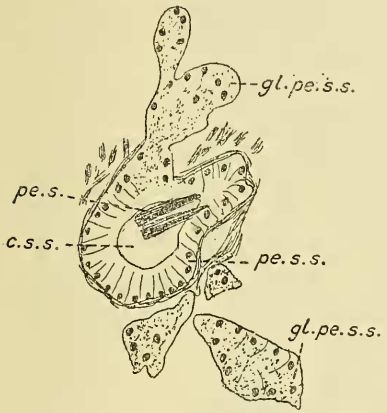
(b) *Internal Anatomy.*

The cuticle lines the spermiducal chamber, which is therefore to be considered as a depression of the ventral body-wall. Large mucous cells are a prominent feature of the surface epithelium; these no doubt secrete the mucus, which with the addition of foreign particles forms the tube of the worm. The cells of the

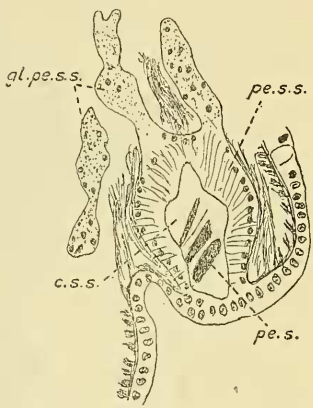
lateral line are small, about 15 by 6–9 μ in size, have an irregular form and contain a conspicuous rounded nucleus of 4 μ diameter; they are only 4–5 in number in each transverse section.

The clitellum extends over segments 7 and 8, which contain the principal genital organs; it leaves free the area on the ventral surface occupied by the spermiducal chamber (Pl. I. fig. 4). It is opaque white in appearance and merges gradually into the epidermis in front and behind. Its cells are about 70 μ in height, *i. e.*, about four times as high as the ordinary epidermal cells. In the clitellar cells the cell outlines are lost, and the nuclei disappear, though these may be visible in the early condition lying here and there near the inner border. The cells have a coarse granular appearance; the mucous gland cells are present in the clitellum also.

Text-fig. 2 A.



Text-fig. 2 B.



Vertical sections through the penial setal sac and the glandular masses in connection with it in two different specimens. The penial seta is rooted in the wall of the setal sac. × 390.

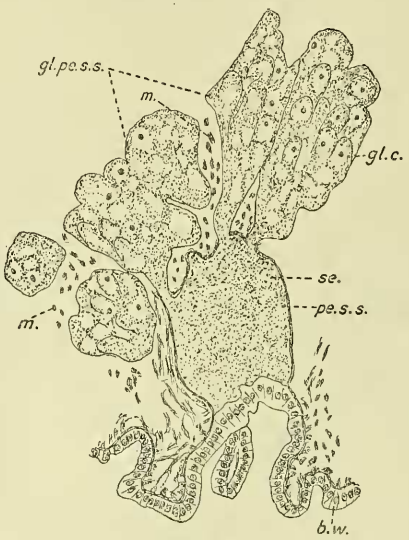
[For explanation of letters used in the figures, see p. 969.]

Setal Sacs.—In the sexual phase the ventral setal sac of segment 7, which contains the penial setæ, is nearly circular in outline as seen in a transverse section of the body (Pl. I. fig. 2). Its wall consists of tall columnar epithelial cells of about 18 by 2·5 μ size, containing a few nuclei near the outer periphery; outside the epithelium there is a thin layer of muscle fibres. Cell outlines are not recognizable in the greater portion of the penial setal sac, except for a small portion on its ventral surface, on account of the secretion, with which the cells seem to be filled; the nuclei are also mostly lost in this region (text-fig. 3), though they are easily recognized in the ventral portion of the wall, where the secretion is not present. The

setal sac is continued below as a tube to open externally, and is there lined by cells which have the same structure as those of the epidermis at the opening, out of which the penial setæ project.

A very obvious feature in the constitution of the penial setal sac is the presence of several conspicuous lobules of a glandular mass, which lie outside it in the body-cavity though connected with its wall (text-figs. 2 A & B and text-fig. 3 & Pl. I. fig. 2). The lobules vary in diameter generally, and each is continued at its narrow inner end into the wall of the setal sac. The various lobules are separated from one another by a few narrow bands of muscle fibres. The epithelial wall of the

Text-figure 3.



Vertical section through the penial setal sac of a specimen in a more advanced stage of maturity. The glandular masses here are much bigger and lobed. The secretion of the gland cells is seen passing into the epithelial wall of the setal sac. × 220.

setal sac, as has been pointed out, does not show any cell outlines for the greater part (text-fig. 3), and this is specially the case where the lobules pass into it, but is filled with a coagulum, which is as a matter of fact the secretion. It seems to me that the secretion of the gland cells which constitute the various lobular masses passes into the epithelial cells and is thus stored up there ; it is also likely that the epithelial cells are capable of secreting too. Each penial seta is rooted only in the innermost portion of the wall of the sac. The whole structure and appearance of the glandular masses and their connection with the epithelium of the setal sac resembles a somewhat similar condition

shown by the prostate and the atrium in these worms, as we shall see later. That the epithelial cells of the setal sac, filled with secretion generally lose their cellular structure, except in the small ventral portion, which is continuous externally with the outer tubular part of the sac and not being connected with the glandular cells is hence devoid of secretion, can be easily followed in sections.

Each glandular mass consists of a number of somewhat elongated pear-shaped cells closely pressed together. The cells have a frothy appearance on account of the secretion they are filled with, have mostly lost their cellular outlines, are deeply stained with hæmatoxylin or similar stains, and are similar to those of the prostate; only a few nuclei are present and all this tends to show that after secreting they lose their structure.

The septa are thin throughout the body. The first septum lies between the third and fourth segments.

Alimentary canal.—The buccal cavity is capable of extrusion; the epithelial cells lining it are devoid of cilia. The pharynx occupies segments 2 and 3, and is covered over by a small amount of chlorogogen pigment; its wall is folded so that about 3–4 diverticula which may be again divided into two arise from it; in one case a fairly long diverticulum arising from the anterior part ran independently for some distance and then opened into its posterior part. The pharyngeal epithelium is composed of high columnar cells with nuclei about the middle of their length, and provided with cilia of large size, which arising from the opposite walls meet in the somewhat narrow lumen of some of the diverticula. In a few specimens having a more slender body the pharynx was not folded, but here the cells of the dorsal wall, about 45–70 μ in height formed a sort of disc-like structure projecting into the pharyngeal cavity, which consequently appeared of a somewhat crescentic form. The cells lining the ventral portion of the wall here were only 27–36 μ in height and 4·5 μ in breadth. Outside the pharyngeal epithelium lies a fine layer of circular muscle fibres, from which fine strands of muscles arise here and there, specially on the dorsal and lateral sides and connect it with the body-wall.

The pharyngeal gland cells lie in groups separated by the muscle strands, which form a sort of loose network around them and largely fill up the body-cavity of the pharyngeal region. Each gland cell takes a deeper hæmatoxylin stain than the rest of the tissues; it consists of a broad outer expanded portion in which lies the nucleus with the nucleolus and a long inner narrow portion, which can be easily mistaken for a connective tissue or a fine muscle fibre. The cell groups surround each of the pharyngeal diverticula referred to before. In sections most of the gland cells are cut in such a way that their long inner stalks become completely separated off from their outer expanded portions and look like fibres. Hence arises a difficulty in tracing the cells to their inner ends. That the fine stalks of the gland cells reach

the fine basal membrane surrounding the pharyngeal epithelium is beyond doubt, and whether they penetrate the epithelium lying in between the cells to open into the lumen I have not been able to see. The pharyngeal gland cells extend also behind the pharynx and lie in masses of a somewhat irregular kind in the body-cavity near the first septum; I believe that these also send processes to the alimentary canal. The œsophagus occupies segments 4–8 and differs from the intestine in its lesser diameter. The epithelium is separated from the surrounding layer of muscle fibres by a fairly continuous sinus, which is interrupted at a few places by the epithelial cells meeting the muscular layer. The œsophagus suddenly dilates about the middle of the 8th or the beginning of the 9th segment to form the intestine, which in structure corresponds to the œsophagus; it occupies most of the available space in the segment and is attached to the body-wall by muscular strands.

A large number of parasites belonging to the group Ciliata Astomata (Pl. III. fig. 12) were found in the intestine of the majority of the specimens.

Blood vascular system.—The blood is yellowish-red in colour and devoid of corpuscles. The dorsal and ventral blood-vessels are the only longitudinal trunks present, and they are connected with each other by a pair of commissural vessels in every segment. The dorsal vessel is contractile and extends throughout the length of the body; it occupies a dorsal position only in the first six segments, after which it turns to lie ventrally on the left side near the ventral blood-vessel. The ventral vessel divides in the first segment to form a pair of slightly coiled vessels which unite above to form the dorsal vessel. The peri-visceral vessels are large and undulating; they lie in the posterior part of the segment in front of the septum. In the region of the pharynx they form a series of loops around it; in the posterior portion of the body they lie very close to the body-wall and make it appear vascular, but they do not branch to form such a cutaneous plexus as is present in some of the Tubificids. In the 6th segment the dorsal vessel communicates with the ventral vessel by a pair of short lateral hearts. The intestine also is surrounded by a sinus, which lies outside the gut epithelium and is interrupted at a few places by the epithelial cells touching the muscular layer outside; it is directly connected with the dorsal vessel by means of a short vessel once in each segment. The dorsal vessel is usually enlarged in the 7th segment, where it turns on the left side; the peri-visceral vessels in the region of the sperm and ovisacs become enlarged in the sexual phase and lie coiled round them. The absence of supra-intestinal and sub-intestinal vessels as well as the parietal network indicates the simple condition of the vascular system, which is emphasized by the presence of a fairly continuous peri-intestinal sinus as in the Naididæ. The vascular system therefore is much simpler than that of *Tubifex*, *Ilyodritus*, and *Branchiura*.

Nephridia.—The nephridia are constructed on the same plan as in *Tubifex*. They are unpaired and lie on one side of the body near the ventral surface close to the ventral blood-vessel. The nephrostome is followed by a short uncoiled tubular portion with thin walls, which after piercing the intervening septum undergoes several windings, before it becomes continuous with the convoluted tube of the glandular mass. A small pear-shaped enlargement of the tube before it passes into the glandular mass is seen only in sections with some difficulty. The tube in the glandular mass is coiled two or three times to form well-marked loops; it then emerges as a somewhat wider tube with thin walls, on ventral side nearer the anterior end of the nephridium, and not at the posterior end as in *Tubifex*. The terminal free portion of the tube is short and expands near the distal end to form a small vesicle, which opens to the exterior at the nephridiopore, a short distance in front of the ventral setæ. The first nephridium lies in the 11th or 12th segment, after which it is present regularly in every segment, except in the terminal portion of the body.

Nervous system.—The cerebral ganglion is deeply cleft in front, slightly so behind. The median lobe, which characterizes the brain of *Tubifex* and other Tubificids is here absent, but a median nerve is given off anteriorly to the prostomium. The peri-pharyngeal cords unite in the 2nd segment to form the first ganglion of the ventral nerve cord. The giant nerve fibres so characteristic of the nerve-cord in the Tubificidæ are absent here.

Genital organs.—I collected on several occasions between the middle of February and the end of April a few specimens having these organs at various stages of maturity. The genital organs are placed far more anteriorly than in any other Tubificid, *i. e.* in segments 6 and 7; in other Tubificidæ they are never present in front of the 9th segment except in *Tubifex* (*Ilyodrilus*) *bedoti*, where they lie in segments 8 and 9. In this respect *Aulodrilus kashi* comes near the family Naididæ, in which the sexual organs lie in segments 5 and 6. The gonads are the first organs to appear when the period of sexual maturity sets in. In one specimen only testes were present; on the other hand where the sexual organs were fairly advanced, the testes had entirely disappeared, having given rise to an enormous mass of developing sperms, which filled the 6th segment and the sperm-sac. The ovaries are always present till the latest stage of maturity and are quite large, as in other Tubificids.

The testes are ovoid masses, one on each side, attached by a narrow base to the posterior face of septum 5/6 near the ventral body-wall.

The ovaries in a stage of advanced maturity are a pair of large massive organs of a somewhat ovoid or irregular form with a small basal stalk, by which they are attached to the posterior face of septum 6/7 near the ventral parietes. They remain throughout the sexual phase, even when the ovisac is filled with ova and

yolky substance—a feature which distinguishes the Tubificidæ from the Naididæ, in which the ovaries disappear early like the testes. Each well-developed ovary measures about ·088 mm. in height and ·095 mm. in breadth; it extends as far back as the cœlomic sac which lies in the hinder part of the segment. It is composed of ova at various stages of maturity, somewhat loosely arranged and not consolidated as in the Megadrili, and a large mass of yolk. The yolk generally fills up a large space in the centre of the ovary, while the ova lie all around it forming the periphery; in two cases, however, the yolk extended on the upper border, and the ova were lying then on the anterior, ventral and posterior margins. It seems probable that only the cells around the periphery of the ovary develop into ova, and that the central cells break up, lose their individuality and form the large amount of yolk-matter. The developing oocytes, when of sufficiently large size get discharged with a part of the yolk and find their way into the ovisac, where they complete their further growth.

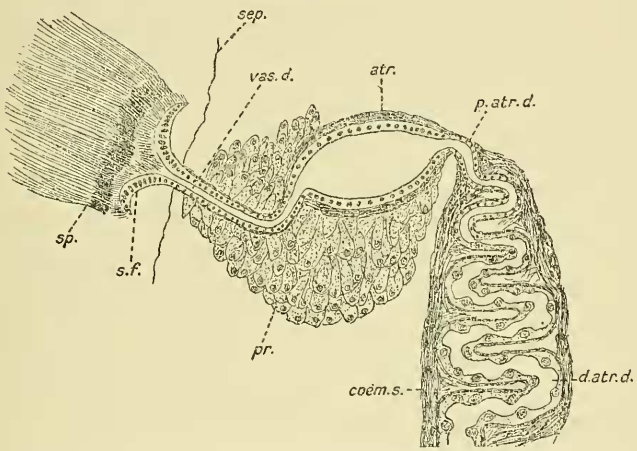
There are no special blood-vessels for the ovary, or any part of the genital apparatus; the peri-visceral blood-vessels and the dorsal vessel become much enlarged in the region of the body containing them.

The vas deferens lies in the 7th segment, and opens internally by a large seminal funnel in the segment in front, piercing septum 6/7; it opens externally in a large ventral depression of the body-wall—the spermiducal chamber. Each duct lies in two segments and consists of the following parts: the seminal funnel, the vas deferens proper, the atrium with the prostate and the atrial duct, which is very long, much coiled and enclosed in a thick coat of muscle fibres to form a spherical or ovoid muscular or cœlomic sac.

The seminal funnels are situated in the 6th segment—*i. e.* the segment in front of that in which the tube itself lies, near the ventral parietes, projecting freely and lying in front of the lower part of septum 6/7, below the opening of the sperm-sac (text-fig. 4). Each funnel about 75 μ in height is cup-shaped with everted lips; in an advanced stage it is wide and shallow reaching about 75 μ in breadth. It is lined by a single layer of columnar ciliated cells of 20–28 μ height except near the margin of the upper lip, where the height is somewhat less; the cells are about 3–6 μ broad, are wider on their inner ciliated border and narrower, appearing somewhat fibre-like at their outer end. The epithelial cells contain large oval nuclei, 5–6 μ in greatest diameter placed about middle of their length; the nuclei are somewhat smaller in the lower marginal cells of the funnel. The cilia are fairly conspicuous. The peritoneal layer does not appear to be present outside the funnel epithelium. The elongated sperm-heads of 11–12·6 μ length with the tails about four times in length lying behind form a regularly arranged dense mass near the funnel opening (text-fig. 4). The lower lip of the funnel lies near the ventral parietes, about 32 μ distance from it.

The vas deferens is a short slightly curved tube leading back from the seminal funnel and opening behind into the anterior end near the ventral margin of a somewhat swollen chamber, the atrium. The duct is circular in transverse section, and of nearly the same breadth throughout, *i. e.* about 25 μ. The lumen is only 4 μ in diameter. It is lined by cubical epithelial cells of 7·5 μ height and without definite cell-outlines; the oval nuclei of 7·5 μ greatest diameter lie at right angles to the height of the cells. Outside the epithelium there is present a thin layer of circular muscle fibres, which as the seminal duct joins the atrium becomes much thicker and is continued into the thick muscular coat of the atrium. A few nuclei seen in sections here and there outside the muscular layer indicate the presence of the peritoneal layer.

Text-figure 4.



Semi-diagrammatic vertical section of the vas deferens apparatus as compiled from several successive sections. × ca. 540.

In the early stage the vas deferens is shorter and runs nearly straight to open at the anterior end of the atrium; it is also narrower, the breadth then being only about 14 μ including a lumen of 2·5 μ. The epithelial cells are cubical, the muscular coat around the epithelium is feebly developed or even in a still earlier stage absent. The epithelial cells of the vas deferens are altogether devoid of cilia, while in the case of *Tubifex tubifex* and *Limnodrilus claparèdeianus* the cilia are quite conspicuous. In the latter genus I had the opportunity of examining the vas deferens on several occasions and found the epithelium provided with long cilia arising from the basal granules, which are visible in the living worm under a high power. It is also interesting to note here, that the vas deferens throughout the sexual phase is short.

What corresponds to the atrium in other forms is a long tubular structure consisting of three parts. The first part, that into which the vas deferens opens, is a dilated chamber, ovoid in form, to which I restrict the term atrium; and the rest of the tube I call the atrial duct. This is much convoluted and enclosed in a thick sheath of muscle fibres which form a chamber—the cœlomic or muscular sac. The atrium has its long axis parallel to that of the body (Pl. I. fig. 3, text-fig. 4; and Pl. II. figs. 5, 6, & 7); in a fully mature form it is about 143 μ in height, 92–114 μ in breadth and 192 μ or about $\frac{1}{5}$ mm. in length; in the posterior portion however, its height is only about 74 μ. Its wall consists of a muscular sheath of 5–7 μ thickness, which is surrounded externally by a thin layer of peritoneum; and of the inner epithelium, which in many of the specimens approaching advanced sexual maturity loses its cellular character, appears simply frothy and stains like the coagulum with which the atrial cavity is filled. Though the cells have lost their structural features and nuclei, it can be recognized that they have increased in size. The cells lining the hindermost part of the atrium retain, however, their columnar outlines and their nuclei. The secretion of the larger, anterior portion of the atrium appears to be similar to that of the prostate cells.

Prostate.—The prostate gland is characteristic of the Tubificidæ among the Microdrili.

Connected with the atrium on its ventral side nearer its rounded anterior end there lies a voluminous mass of gland cells, which surrounds it, and a greater portion of the vas deferens in front; it has the form of an irregularly shaped lobate mass, sometimes reaching as far back as the cœlomic sac. The mass lies dorsally to the ovary, which occupies a ventral position in this region of the body (Pl. I. fig. 3). The cells are large and pear-shaped with the nuclei contained in the outer swollen portion; their narrow inner portions or fine ductules lie near the centre of the gland (Pl. II. fig. 5) and converge towards the point where the prostate is in communication with the atrium, while the broad outer portions of the cells lie towards the periphery. When the prostate is fairly well developed, which was the case in most of the specimens under examination, the ductules or the inner portions of the cells lose their entity and become more or less disorganized; and in the period of more advanced maturity, the outer portions of the cells become more or less dissolved, and the cellular structure disappears, only a few nuclei being left here and there. As the cells lose more and more in structure, the secretion becomes collected in a mass and passes straight into the atrium, where the prostate is connected with it (Pl. II. figs. 6 & 7). The prostate communicates with the atrium by an opening 42 μ wide; here both the muscular and epithelial layers of the atrial wall are absent, so that the prostate appears to arise as an outgrowth of the atrial epithelium. In the mature worm the atrial

epithelium is thus replaced by a mass of secretion, which has apparently originated in the prostate. Vejdovsky (16), who studied the development of the atrium and the prostate has stated that the latter is formed by the proliferation of the cells of the lining epithelium of the atrium at a point, where the muscular and peritoneal layers are interrupted, so that the prostate cells and those of the atrial epithelium are intimately connected with one another; this agrees very well with what I find in sexually mature specimens. Though I am not in a position to say anything at present as to the origin of the prostate, its connection with the atrium certainly suggests its origin from the latter. It is, however, clear beyond doubt that the prostate cells become disorganized when full of secretion, especially in their long inner ductule-like portions, and the secretion is discharged mechanically as a stream of inwardly moving fluid running through the centre of the glandular mass into the atrial cavity at the point of communication.

Muscular or cœlomic sac.—The atrium is followed by a narrow duct of about the same diameter as the vas deferens, which after a short length of about 22 μ undergoes a few irregular windings and may be called the proximal portion of the atrial duct (or the middle portion of the atrium, if it is regarded as a part of the atrium itself). It is continued into a longer and much wider terminal part, which also undergoes several windings, fairly regularly arranged one below the other, till it passes vertically downwards to open into the spermiducal chamber. The convoluted middle and distal regions of the atrium which constitute the atrial duct are bound up together and enclosed by a thick coat of muscle fibres so to form an ovoid structure, somewhat similar to the cœlomic sac of *Branchiura* and *Kawamuria*; the muscle fibres forming its walls are not compactly arranged, but somewhat loosely connected, so that there are left some narrow spaces here and there in between the strands of fibres, which have a few nuclei at certain places. The muscular sac extends ventrally as far as the spermiducal chamber; the muscle fibres forming the wall are continued in places as strands above and below into the musculature of the adjacent body-wall, where they pass through the layer of longitudinal muscle fibres to reach the layer of circular muscle fibres, and thus attach the sac to the body-wall. The height of the sac varies ordinarily from 182 μ to 240 μ; in a specimen of smaller size it was 125·5 μ; its breadth varies from 115–182 μ. The narrow proximal portion of the atrial duct is 14–17 μ in diameter, having a lumen circular in transverse section with a diameter of about 5 μ; it occupies the topmost portion of the muscular sac, in front of which it leads out from the atrium. It is lined by cubical cells of size 1 by 3 μ with conspicuous nuclei, but no definite outlines; outside it there is a thin layer of circular muscle fibres, which is continuous in front with the thick muscular wall of the atrium.

The epithelial cells of the wider distal portion of the atrial

duct are of a different appearance altogether. They are not of the same uniform height throughout, being tallest about the middle, where they are 8·5 μ high; they are 14·3 μ broad at the base; the inner portion of the cell projects into the lumen and contains the prominent rounded nucleus of 3·5 μ diameter (text-fig. 4; Pl. II. figs. 6 & 7). The atrial duct in this region is much thicker than in the proximal part, being about 28–40 μ in diameter as it gradually descends towards its termination: its lumen is 16–22 μ wide. Outside the epithelium there is a covering of muscle fibres, which is slightly thicker than that of the proximal part of the duct owing to the presence of an additional layer of longitudinal muscle fibres external to the circular layer.

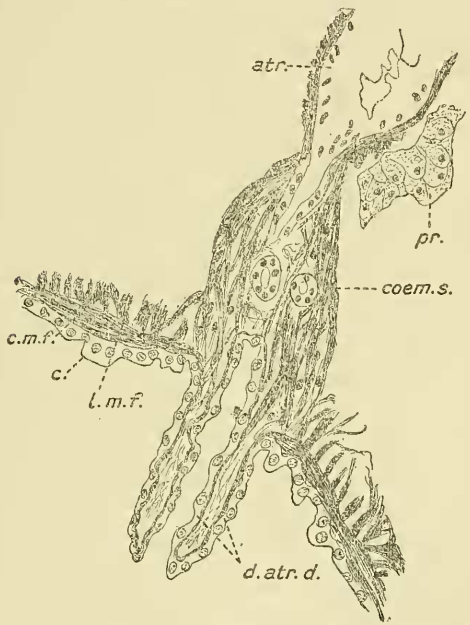
The paratrium, a blind tubular outgrowth of the atrium characteristic of *Branchiura*, *Kawamuria*, and *Bothrioneuron* is here absent.

The spermiducal chamber is the median quadrangular depression on the ventral surface in the 7th segment formed as an invagination of the body-wall. The term has been used by Goodrich for a similar structure in *Vermiculus*. The chamber is large, about 115 μ deep, 200–250 μ long and about 360 μ broad; the margin of its external opening is generally puckered. The openings of the atrial ducts lie inside at its anterior angles, one on each side, and in several specimens during life one or two penes were seen projecting out of it; sometimes, though rarely, the chamber is everted to form a papilla-like structure bearing the openings of the atrial ducts on its surface. The diameter of the terminal portion of the atrial duct near its opening is about 32 μ, and the epithelial cells lining it gradually become of a uniform size, till they have the same form as those lining the inner wall of the chamber, which is the inturned epidermis. The cuticle of the epithelial lining of the chamber is continuous with that of the body-wall outside. The spermiducal chamber acts probably as a sort of sucker during copulation. Although there is no direct muscular mechanism for deepening the chamber, the radiating muscle fibres attaching the muscular sacs to the body-wall by contraction can indirectly pull it to a certain extent and thus deepen it to produce a sucker mechanism. The chamber was more deepened in the specimen in which the penis was protruded; and it appears that the contraction of the muscle fibres of the muscular sacs, which lie on its top, helps in deepening the chamber also.

Penis.—While examining several specimens in the living condition I saw in some cases one or two long cylindrical soft penes projecting out of the spermiducal chamber for a long or short distance. After proper fixation, sections were cut of two such specimens and the structure of the penis was investigated. This organ is covered externally by epithelium which is really the inner wall of the wide terminal portion of the atrial duct, and can be distinguished as such by the peculiar character of its cells, which

are high and low at regular intervals, and swollen at their inner projecting borders, which here lie outwards; the layer of muscle fibres outside the epithelium in the atrial duct forms here the inner wall (text-fig. 5). In the centre of the penis is a tube—a part of the atrial duct, the wall of which is continuous with that of the outer tube at the terminal opening. It is obvious therefore, that the penis is here formed by the eversion of the terminal portion of the atrial duct carrying with it the more proximal part as the central tube. The narrow proximal portion of the atrial duct does not seem to be drawn into the penis. The

Text-figure 5.



Part of transverse section of the body through the penis, cœlomic sac, and a part of the atrium and prostate. × 390.

eversion of the atrial duct is in all probability brought about by the contraction of the muscle fibres forming the muscular sac, which in turn are connected with the muscular layer of the body-wall. The penis in these worms is not a permanent structure and hence is very different from that in many Tubificids; it should be regarded as a pseudo-penis.

The sperm-sac is a median pouch formed by the extension backwards of septum 6/7; it opens anteriorly by a wide mouth in the 6th segment, and lies generally dorsal to the œsophagus in the 7th and a part of the 8th segments. Its walls are as thin as

the septum from which it is formed and consist of a thin layer of muscle fibres covered both on the inner and outer sides by a peritoneal layer of thin flattened cells. It is filled with sperms in various stages of development, and is in appearance and structure similar to the sperm-sac in the Naididæ.

A large portion of the body-cavity in the 6th segment is separated off laterally and ventrally from the smaller peripheral portion, contains all the organs belonging to the segment, and is filled with a huge mass of developing sperms. This part is surrounded by a wall, which is continued dorsally into the body-wall, its side walls become continuous ventrally to form the ventral portion of the wall, except at the ventro-lateral corners where the spermathecal ducts interrupt it as they pass out to their openings, and in the transverse sections of the worm here the peripheral chamber is thus divided up into a median ventral and two lateral parts (Pl. II. figs. 8 & 9). The wall which so separates the two portions of the body-cavity in the segment is composed of modified peritoneal layers, with a layer of circular muscle fibres in between. The outer peritoneal layer consists of branched cells of an irregular outline, the fibrillar branches given off from the various cells anastomose forming a sort of loose network, which with fairly big spaces enclosed in between gives the whole layer the appearance of parenchyma and is about five times as thick as the rest of the wall (Pl. III. fig. 10). The middle layer, consisting of circular muscle fibres, becomes continuous with the same layer of the ventral body-wall at the openings of the spermathecal ducts. The inner layer consists of cells fairly regularly arranged and not of the same breadth throughout, less regular on the lateral portions of the wall. This layer is continued dorsally into the peritoneal layer of the body-wall, which also in this segment may be parenchymatous in character, hence sometimes the whole peritoneal cavity, *i. e.* the space outside the wall of the central chamber, is filled with parenchymatous tissue formed by these peritoneal layers. The wall of the central chamber in the front and hinder parts of the segment gradually comes near the body-wall, and consequently the peripheral cavity becomes much more reduced; posteriorly it completely joins the body-wall about the level of the ventral setæ, in front of the seminal funnel; anteriorly it unites with the body-wall near septum 5/6, of which it appears to be a backward continuation, for in structure like the septum it is composed of three layers, the outer and inner peritoneal ones of more or less parenchymatous character with the middle one of muscle fibres. It seems clear that a good deal of support is afforded to the spermathecal ducts and proper protection to the developing sperms by this arrangement.

The anterior sperm-sac described in many Tubificids is here absent. The ovisac is formed as a pouch by the extension backwards of septum 7/8 and lies in segment 8, extending behind nearly to septum 8/9. It surrounds a part of the sperm-sac and extends

about $\frac{1}{3}$ mm. distance behind it. It is filled with a large mass of yolk granules, and also contains a number of ova at various stages of maturity.

The female funnel is very small. Its posterior wall (the one nearer the septum behind) is represented by a patch of columnar epithelial cells of about 25 μ by 5 μ size lying on the anterior face of septum 7/8 near the ventral parietes, below the point where this septum is bulged backwards to form the ovisac. The anterior wall is, however, smaller and somewhat less conspicuous in sections. The epithelial cells of the funnel contain oval nuclei of 2·5 μ diameter.

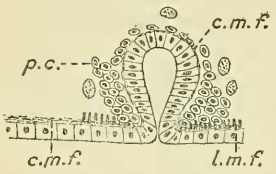
The oviduct is extremely short, about 40 μ in length; it runs backwards and downwards somewhat obliquely to pass through the body-wall, through which it runs as a narrow irregular channel of about 25 μ length and 4 μ breadth. The female opening is wider at the inner margin of the epidermis and narrower at the outer.

The spermathecæ occupy segment 6; they lie freely for the greater part of their length in the central chamber of the body-cavity and are attached to the partition wall at the ventro-lateral corners as they pass downwards to their openings, which lie about the middle of the segment, much in front of the ventral setæ. They are of considerable length and bent, so that each consists of two parts, a vertically elongated terminal portion—the duct, and an inner sac-like portion—the ampulla. The duct is not sharply marked off from the ampulla, but gradually passes into it. The ampulla is simple, and in the later stages of maturity quite large. The length of the spermatheca is 234–305 μ. The duct is circular in transverse section, about 88–133 μ in length and 48·5 μ in diameter; in one case it measured 175 μ in length. Its wall is 17–20 μ thick, and is composed of an inner lining of columnar epithelial cells, surrounded by a coat of muscle fibres, with a thin layer of peritoneum outside. The epithelium is composed of a single layer of tall columnar cells of 10–14 μ height and 3 μ diameter, containing oval or somewhat elongated nuclei near the periphery, which lie with their long axis parallel to the height of the cells. The muscular sheath of 2 μ thickness consists of an inner thin layer of circular muscle fibres and an outer thicker one of longitudinal muscle fibres. The peritoneum as usual consists of a layer of thin flattened cells with prominent nuclei. Near the opening the wall of the duct is less thick than in the upper part; the epithelial cells here are less tall, being nearly of the same height and form as those of the epidermal cells with which they are continuous; here the muscular coat is also thinner and is continued into that of the body-wall. The nuclei of the epithelial cells in the terminal part are not elongated, but somewhat rounded, and lie about the middle of the cell. The ampulla is much larger than the duct; its length varies considerably—in three specimens it was 145, 185, and 295 μ; the maximum breadth was about 120 μ. Its wall is much thinner than that of the duct,

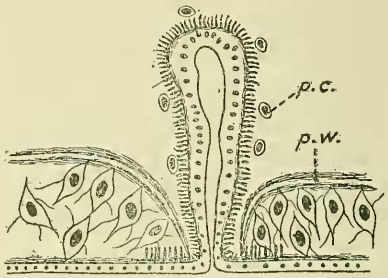
but the three layers are recognizable. The epithelium consists of cubical cells of not more than 6·5 μ height; in the advanced stages of sexual maturity the cells lining the inner blind portion are still lower, while those near the duct are somewhat square in outline. The muscular portion of the wall is much thinner, and consists of the same layers as in the duct. The thin peritoneum continuous with that of the duct forms the outermost layer. The greater thickness of the wall of the duct is due to the greater height of its epithelial cells and thickness of the muscle layers.

In one specimen the spermathecæ were found to be in an early stage of development (text-fig. 6). Here it has the form of a small rounded chamber with an external opening and is not differentiated into duct and an ampulla. In size it measures 120 μ by 90 μ. Its epithelium is composed of tall cells with oval nuclei lying about the middle and is surrounded on each side by a mass of small peritoneal cells with prominent nuclei, a few of which are

Text-fig. 6.



Text-fig. 7.



Stages in the formation of a spermatheca. × 840.

continued to form a thin layer above. There is no layer of muscle fibres present outside the epithelium, the cells of which have the same form and structure as those of the epidermis, with which they are continuous. In another specimen the spermathecæ are better developed, and one of them was about 160 μ by 68 μ in size; here they have the form of an upright tube with an external opening. It is composed of columnar cells with conspicuous nuclei lying fairly near the periphery. Outside the epithelium a thin layer of circular muscle fibres surrounded by a few peritoneal cells is present, but the layer of longitudinal muscle fibres is not yet formed. The wall is 22 μ thick and the lumen 13 μ wide. Here also there is as yet no indication of the ampulla (text-fig. 7). The spermathecæ thus arise as small rounded sacs by an invagination of the epidermis, then they assume a tubular form, but the differentiation into the duct and ampulla takes place much later. In both these cases there were no spermatozoa in the spermathecæ.

(4) Aulodrilus stephensoni, sp. n.

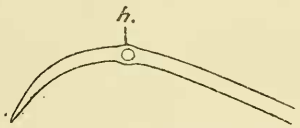
All the worms I obtained conform to the above description with the exception of one. This was first examined in the living condition and then studied from longitudinal sections. The description, though far from complete, gives the main features of the anatomy.

(a) *External Characters.*

The length is about 17·5 mm. The prostomium is bluntly conical. The number of segments is 56. The spermathecal openings lie on the ventral surface in the 9th segment much in front of the ventral setæ. The spermiducal chamber lies on the ventral surface of the 10th segment: as it is very shallow, the opening of the atrial duct is clearly seen in each of its antero-lateral corners. During the examination of the living worm this chamber was not made out and the openings of the atrial ducts were supposed to be paired male openings; but the closer examination of the entire mount and subsequently the sections revealed the presence of the shallow chamber.

Setæ.—Dorsal and ventral setæ are present in all the segments from the 2nd segment backwards. The dorsal setæ are about 3–9 per bundle, each bundle being composed of 2–3 hair setæ, and 1–6 sigmoid needles. The uncinate seta (text-fig. 8) is about

Text-figure 8.



Uncinate seta of *A. stephensoni* as seen in balsam preparation of the entire specimen. × 540.

half the size of the hair seta and ends in a fine point at the distal extremity. The small narrow outer process, or the distal prong which is present in the setæ of *A. kashi*, is not seen. It may be that its absence is due to breakage while making preparations. The nodulus is situated at about one-third of the distance from the distal end, and the distal portion of the shaft beyond it projects outside the body-wall.

The ventral setæ are similar to the dorsal needles and are 7–10 in a bundle. The penial setæ are the modified setæ of the 10th segment and are 1–2 in a bundle; they lie in the spermiducal chamber slightly outside the opening of the atrial duct. In shape and length they appear like those of *A. kashi*; the breadth near the base is about 5–7 μ.

(b) *Internal Anatomy.*

The clitellum is twice as thick as the general epidermis and occupies segments 10 and 11.

The penial setal sac is large, rounded, about 102 μ in diameter. Its wall is about 30 μ thick and the lumen 42 μ in diameter. In connection with the sac there is a large glandular mass similar in structure to that in *A. kashi*. The first septum lies between segments 3 and 4.

The pharynx extends up to the 4th segment, in which the œsophagus begins. The intestine commences in the 9th segment; it is larger till the 20th segment, after which it gradually narrows towards the posterior end, where again it slightly broadens, being stretched by a few muscle fibres, which attach it to the body-wall.

The dorsal and ventral blood-vessels are connected by an undulating commissural vessel in every segment. From the sections I have been able to find the position of hearts in segment 8.

The testes had disappeared, but a large mass of developing sperms fills up the central chamber of the 9th segment and the sperm-sac as in *A. kashi*. The structure and position of the seminal duct, prostate, atrium and muscular sac agree in essential respects with the description of these organs in *A. kashi*. The seminal funnel is cup-shaped with everted lips appearing somewhat like a thistle funnel; it is attached near the ventral parietes to the anterior face of septum 9/10 and lies in the 9th segment. The columnar epithelial cells lining it are 14–20 μ in height. The vas deferens (text-fig. 9) is short and 17 μ in diameter, its wall being 6 μ thick; its lumen is 5–6 μ in diameter; it is lined by cubical epithelial cells, which are covered by a thin layer of circular muscle fibres. The atrium is very much like that of the other species, but it is smaller, being 80 μ by 45·6 μ in size and lies here in the 10th segment. The cells lining the cavity have lost their cellular appearance owing to the secretion with which they are filled, and are surrounded by a thick muscular sheath.

The prostate is large and massive; it extends behind as far as the muscular sac. It is similar in structure to that in *A. kashi*, and opens here also into the antero-ventral border of the atrium.

The atrial duct (text-fig. 9) is much convoluted; it consists of proximal and distal portions, and is enclosed by a thick covering of muscle fibres which forms the muscular (cœlomic) sac. The atrial duct as it leaves the atrium and before it enters the muscular sac is 23 μ in diameter. Its lining epithelium consists of cubical cells, outside which there is a thin layer of circular muscle fibres. The proximal portion of the atrial duct is larger and has a wider lumen—about 11 μ—than in *A. kashi*. The distal portion of the atrial duct is 31 μ in diameter and is lined by an epithelium, which as in the other species is alternately

high and low. In the taller portions near the inner margin are the nuclei. The muscular sac is smaller in this species; it is about 140 μ in length and 114 μ in height.

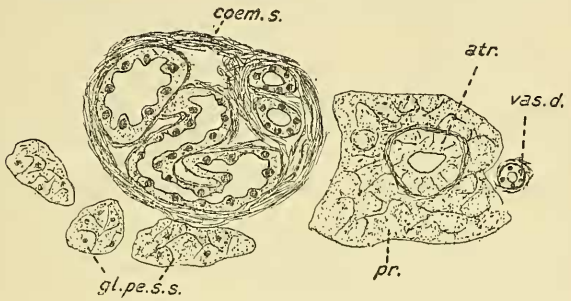
The sperm and ovisacs are formed here by extension backwards of septa 9/10 and 10/11 respectively.

The peripheral portion of the body-cavity in the 9th segment is separated here also by a partition as in *A. kashi*.

The ovaries are large and attached to the posterior face of septum 9/10 near the ventral parietes lying in the 10th segment.

The spermathecæ lie in the 9th segment; in structure they are similar to those in the other species, except that the duct here is somewhat smaller.

Text-figure 9.



Longitudinal section through vas deferens apparatus of *Aulodrilus stephensoni*. × 220.

The present species is principally distinguished from the former by the position of the genital organs, which here lie in segments 9 and 10. The seminal funnel lies in the 9th segment, while the rest of the efferent apparatus occupies the 10th segment. The sperm-sac and ovisac are formed by septa 9/10 and 10/11. The spermiducal chamber is very shallow and lies in segment 10. The uncinate setæ are somewhat different from those of the other species, and the penial setæ are the modified setæ of the 10th segment.

(5) Remarks on the Systematic Position of these Worms.

It will be apparent from the above description that *Aulodrilus* must be referred to the family Tubificidæ, although in *A. kashi* the anterior position of the genital organs, which lie here in segments 6 and 7, suggests a position closer to the Naididæ, in which family these organs lie in segments 5 and 6. In *A. stephensoni* however, the sexual organs are present in segments 9 and 10, though in other structural details there does not seem to be any marked difference between the two species. This clearly decides the position of this genus in the Tubificidæ. Another point, in which these worms resemble the Naididæ, is the presence

of only one sperm-sac, which in appearance and structure is quite similar to that in the Naididæ; the anterior sperm-sac, which is present in many Tubificids is not present here. The main portion of the body-cavity in segment 6 or 9 is cut off from a peripheral portion, and forms the central chamber, which contains all the organs and is filled with the developing sperms—a peculiar feature of this genus. That the worms do not reproduce asexually by budding, which is a common occurrence in the Naididæ, separates them sharply from that family. There are, however, some features in which *Aulodrilus* shows a simplicity of structure comparable to that met with in the Naididæ, *e. g.* in the vascular system, where the presence of hearts in the 6th segment in *A. kashi* * and the absence of supra- and sub-intestinal vessels and integumental network is noteworthy; the brain also is without a median lobe, and there are no giant nerve fibres in the ventral nerve-cord.

The distinct Tubificid characters are as follows:—

(1) Structure of efferent apparatus with an atrium and massive prostate followed by a long convoluted atrial duct enclosed in the muscular or cœlomic sac.

(2) Constant presence of a large ovary throughout the sexual phase.

(3) The large massive prostate is connected with the atrium as in *Tubifex* and some other Tubificids. It appears to be developed as an outgrowth of the atrial epithelium.

(4) Presence of a spermiducal chamber.

(5) Position of genital organs in *A. stephensoni* in segments 9 and 10.

(6) Penial setal sacs provided with large massive glands as in *Tubifex* (*Peloscolex*) *velutinus*. The penial setæ are also very long like those of the above species, and very different from the ventral setæ.

The anterior position of the genital organs in *A. kashi*, I think, is a character only of specific rank not showing in any direct way a closer relationship to the Naididæ, for in some genera such as *Megascolex* and *Buchholzia* † there are a few species in which the genital organs are placed one or more segments in front of those, which they generally occupy in the genus. In *Tubifex* (*Ilyodrilus*) *bedoti* the genital organs lie in the 8th and 9th segments and hence more anteriorly placed than in other members of the family. Among the Tubificidæ *Aulodrilus* seems to have relations on the one hand to genera *Tubifex*, *Ilyodrilus*, and *Psammorcytes*, and on the other to *Branchiura* and *Kawamuria*. In possessing hair setæ, the long penial setæ and the massive glands in

* In *A. limnobius*, *A. pleuriseta*, and *A. remex* also the hearts lie in the 6th segment.

† In *Buchholzia appendiculata* Buchholz, these organs lie in the 7th and 8th segments, while in *B. fallax* Michaelsen, they occupy the usual position in the family, *i. e.*, in segments 11 and 12.

connection with the setal sacs, and in the absence of the paratrium this genus resembles *Tubifex* and *Psammorcytes*. But it differs from these genera in the following important points :—

(1) Position of the zone of formation of new segments some distance in front of the anus.
(2) Presence of a spermiducal chamber.
(3) Presence of a muscular or cœlomic sac.
(4) Variable position of genital organs.
(5) Absence of spermatophores and a true penis.
(6) Absence of supra-intestinal and parietal vessels.

In possessing hair setæ, an anterior atrium and a cœlomic sac, and in having no spermatophores, it bears a remarkable resemblance to *Branchiura* and *Kawamuria*, the chief differences being the absence of a paratrium, the presence of penial setæ and a spermiducal chamber, and the absence of a true penis, which is said to be present in *Kawamuria*.

Aulodrilus resembles *Monopylephorus africanus* Michaelsen, in possessing a spermiducal chamber, penial setæ, and spermathecæ in the 9th segment, and in the absence of spermatophores and a paratrium.

The spermiducal chamber perhaps acts as a sucker during copulation. As this structure is present in *Monopylephorus*, which is however, in other respects very different from the present genus, I think this organ is correlated with the absence of a true penis and therefore probably is due to convergence in these genera.

(6) Summary.

(1) The diagnostic characters of the genus and the species are given.

(2) The reproductive organs hitherto unknown are described in detail.

(3) The prostate is large and massive; it opens into the atrium near the antero-ventral margin. The prostate cells soon after they are functional and filled with secretion lose their structure and become disorganized, while the secretion passes as an inwardly moving mass into the atrium at the point where the gland is connected with it. The atrial epithelium also at this time undergoes a great change on account of the secretion by which its cells become replaced having lost their entity. The manner of connection of the prostate with the atrium suggests its origin as an outgrowth of the atrial epithelium.

(4) The cœlomic cavity in the segment which contains the spermathecæ is separated off from the peripheral portion by the formation of a ventro-lateral wall, which is composed of a central muscular layer surrounded on either side by a peculiar parenchymatous tissue of peritoneal origin. The central chamber thus formed contains all the organs of the segment and is also filled with the developing sperms; the spermathecal ducts pass through the ventro-lateral corners of the wall on their way to the exterior.

(5) The spermathecæ are ectodermal in origin, and arise as an invagination from the epidermis.

(6) As regards its systematic position *Aulodrilus* belongs to the Tubificidæ, although it resembles the Naididæ in some of its features. Among the Tubificidæ it is related to *Tubifex* and *Psammorcytes* on the one hand, and *Branchiura* and *Kawamuria* on the other. The spermiducal chamber, which is present in *Monopylephorus*, also seems to be independently derived in these genera, and perhaps acts as a sucker during copulation.

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EXPLANATION OF THE PLATES.

Explanation of Letters used in Figures.

a. anus; *atr.* atrium; *ap.at.d.* aperture of atrial duct; *atr.d.* atrial duct; *b.v.* blood-vessel; *b.w.* body-wall; *c.* cuticle; *c.c.* central chamber; *cl.* clitellum; *cœm.s.* cœlomic (muscular) sac; *c.m.f.* layer of circular muscle fibres; *c.s.s.* cavity of setal sac; *d.b.v.* dorsal blood-vessel; *d.atr.d.* distal portion of atrial duct; *e.gl.c.* epidermal gland cell; *fem.f.* female funnel; *gl.c.* gland cell; *gl.pe.ss.* glands in connection with penial setal sac; *int.* intestine; *l.m.f.* layer of longitudinal muscle fibres; *l.p.w.* lateral portion of partition wall; *m.* muscles; *meg.n.* meganucleus; *n.* nodulus of seta; *o.* opening of vas deferens into atrium; *œs.* œsophagus; *ov.* ovary; *ovis.* ovisac; *p.atr.d.* proximal portion of atrial duct; *p.c.* peritoneal cells; *pe.s.* penial seta; *pe.s.s.* penial setal sac; *per.c.* peripheral chamber; *ph.* pharynx; *pr.* prostate; *pro.* prostomium; *pr.s.* prostate secretion; *prolif.* proliferating cells; *p.w.* partition wall; *s.* seta; *se.* secretion; *sep.* septum 6/7; *s.f.* seminal funnel; *sp.* sperms; *sp.ch.* spermiducal chamber; *sp.s.* sperm-sac; *spth.* spermatheca; *spth.op.* spermathecal opening; *v.n.c.* ventral nerve cord; *vas.d.* vas deferens; *v.b.v.* ventral blood-vessel; *v.p.w.* ventral portion of partition wall.

[Figs. 1–12 illustrate *Aulodrilus kashi* and fig. 13 *Aulodrilus stephensoni*. All the figures except 1, 3, and 13 are drawn with camera lucida.]

Fig. 1. Ventral view of anterior portion of the worm showing spermathecal openings in the 6th and spermiducal chamber in the 7th segment. Penial setæ and apertures of the atrial ducts lie in the spermiducal chamber. × ca. 95.

Fig. 2. Transverse section through the penial setal sac. × 220.

Fig. 3. Semi-diagrammatic, compiled from several successive longitudinal sections showing the genital organs. × ca. 120.

Fig. 4. Transverse section of the body through the spermiducal chamber and its opening. × 120.

Fig. 5. Transverse section showing the prostate opening into the atrium. The prostate and atrial epithelial cells have mostly lost cellular structure and are converted into the secretion. × 390.

Figs. 6 & 7. Longitudinal sections through the prostate, atrium, and cœlomic sac. The prostate cells are disorganized, having lost their structure, and the secretion passes in a mass into the atrium. The atrial cells have also lost their entity, being replaced by the secretion. × 390.

Figs. 8 & 9. Transverse sections in the spermathecal region. The cœlomic cavity in the 6th segment is divided by a partition wall into a central chamber and a peripheral portion. In fig. 8 one spermatheca is opening to the exterior. × 95.

Fig. 10. A part of section in fig. 8 highly magnified. The partition wall consists of a circular layer of muscles in the middle with a layer of parenchymatous cells on either side. × 540.

Fig. 11. Terminal portion of the body. The part just in front of the anus shows no signs of formation of new segments. × 97.

Fig. 12. Ciliate astoma parasites.

Fig. 13. Ventral view of a part of the body in *A. stephensoni* showing spermathecal openings in the 9th and shallow spermiducal chamber with penial setæ and openings of atrial ducts in the 10th segment. × ca. 95.